EXPLANATION of the PRINCIPLES
AND USE OF A
New conſtructed Quadrant.

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NO Inſtrument uſed for Nautical Purpoſes, has I believe undergone more alterations than the Reflected Octant, ſince its firſt being made public by J. HADLEY, Eſq. in the Year 1731, yet has not any one extended its uſe in meaſuring angular Diſtances beyond that of 120° with one Arc only, and with one ſweep of the Index, that in the form of the Sextant now in uſe, is the only Inſtrument for that purpoſe uſed at Sea.

The Improvements which have heretofore been made are chiefly confined to the Adjuſtments of the Glaſſes, both in the fore and back obſervation, and the Accuracy of dividing the Inſtrument by a Machine Invented by Mr. *Ramſden*, and another machine on the ſame principle, made by Mr. *Troughton*, for that purpoſe, notwithſtanding the above improvements the ſextant in its preſent form is inadequate to the purpoſe for finding the Longitude at Sea, at all times, and to other purpoſes, by not taking in an angle of more than 120°, nor indeed beyond 100° with eaſe and accuracy, for reaſons

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that will be hereafter alledged. As to the other method of taking angular Diſtances beyond 90°, by the back Obſervation of *Hadley's* Octant, I believe it to be little known, and ſtill leſs practiſed, the Glaſs for that purpoſe being generally omitted in the beſt Sextants and Octants, yet as the diſtance of the Moon from the Sun for obtaining the true Longitude, is now univerſally acknowledged to be the beſt method uſed at Sea, I therefore hope to meet with the approbation and encouragement from Gentlemen of the Navy, and all others that are curious in their Inſtruments for taking angles, as this new conſtructed Quadrant will meaſure all angles from 0 to 150 or 160°, without moving the Sight Vane or Teleſcope thereon from its place, and with one ſweep of the Index over the graduated Arch, if the Inſtrument be made one fourth or fifth part of a Circle; alſo the ſame thing is done by the Sextant or Octant made on the ſame principle, the Index Glaſs being firſt adjuſted to 90° as will be hereafter deſcribed. The Obſervation is alſo taken with as great or greater degree of accuracy, than can at preſent be done by the beſt Sextant, in the uſual way of obſerving, for here you will have but half the error in the glaſs, and double the width of Illumination or field of View; the method of Adjuſting the Glaſſes is alſo new and more accurate than by the method commonly uſed, as will be hereafter deſcribed in its proper place, the Glaſſes alſo may at all times be proved to be parallel to each other, and at right angles to the plane of the Quadrant in every part; a ſimple method likewiſe preſents itſelf, by which you may plainly diſtinguiſh that your Obſervations, are made truly parallel to the plane of the Inſtrument.

Plate 1,

Plate 1, Fig 1.

The Theory of which is as follows.

A RAY of Light LA, falling on the Glaſs CB, which repreſents the Index Glaſs for the common Octant or Sextant, will be reflected to F, the centre of the Horizon Glaſs GH, from whence it will be again reflected to the Eye at O, the Line OF being the Horizon Line and parallel to KA, LM being perpendicular thereto.

Let MA be a Ray of Light falling on the Index Glaſs DE of the New Quadrant, which will be reflected to F as before, and from F to the Eye in the Horizon Line FO, the angle PAN being right, and AN = AP, therefore the angles NAP, and PNA, are equal, which ſhews that in this Poſition of the Index glaſſes in both Quadrants, the ray will be reflected ſo as to fall on the ſame point in the Horizon Glaſs at F, and the reflected angle AFO, will be the ſame in both, although the angle of Incidence LAB in the Octant is only 22°. 30′, but in the new Quadrant the angle of Incidence MAF = 45°, which is double the former. But the angle LAB = the angle FAC, and both together make 45°, by reaſon of the angle of Incidence being equal to the angle of Reflection, which is again equal to the angle FAK, the exceſs of the angle LAF, above a Quadrant.

Conſequently there are 90° difference in the poſition of the new and old Quadrant Index Glaſſes. This is alſo farther Illuſtrated in fig 1. plate 2d. where the new and old

Quadrants are repreſented in a Comparative view as to their field of Illumination.

This New Conſtruction would alſo admit of the Horizon Glaſs to be of an equal width with the Index Glaſs, and return a full field from the rays falling thereon, when the angle to be meaſured is 90°, after which it will begin to decreaſe as the angular diſtances of the glaſſes increaſe; but even at 180°, it will be equal in width of Illumination, with that of the common form at 90°, as may be ſeen by Inſpection.

Let the poſition of the Glaſs HI and FG repreſent thoſe of the back Obſervation in *Hadley's* Octant, Plate 2nd, fig 1*ſt*.

The angles *bc* E, and *cb* E, are = and each 45° either of which being ſubtracted from 180° leaves 135°, = the angle *cba*, = *tcb*, the angle of Incidence being ever equal, the angle of Reflection, the Angle *bc* G, = Angle *tc* F = Angle *ab* I = Angle *cb* H, therefore if the Angle *tcb*, be taken from 180° will leave the ſum of the angles *tc* F + *cb* G half of which is the Angle *tc* F = Angle XGF = 22° 30′ and making the width of the Glaſs FG Radius, the width of the Illumination will be as the ſine of 22°. 30′. = the ſine of the Angle XGF.

In order to make a Compariſon betwixt the width of Illumination in this, with that of the new invented Quadrant, you ſtill retain the ſame width of Glaſs in each.

The Angle MEQ = 45° = Angle ESR which taken from 180° leaves 135°. equal the ſum of the angles KSE and LSR or the Angle KSE + Angle LSR = 135° but by reaſon of the Angle of Incidence being equal the Angle of Reflection, the Angle KSE = Angle LSR = 67° 30′ = half 135° but the Angle KSF added to the Angle ESR = 112. 30′ = Angle KSR, which again taken from 180 leaves 67.

30′. = Angle KSx. Now KL in the Quadrant = FG in the Octant and the ſine of 67°. 30′. is in this Caſe the width of the Illumination in the new Quadrant, wherefore the width of the former to the width of the latter will be as 38263 to 92387, or nearly as 2 to 5.

The Figures 3 and 4 are repreſentations of the common Sextant and the new Quadrant with the Index ſet to 120° in each, by which at one view is ſeen the difference of the width of Illumination, they being both drawn to the ſame ſcale.

N. B. The obliquity of the rays falling on the Index Glaſs when the Angle exceeds 100°, not only occaſions a very ſmall field in the common Sextant, but ſhews thoſe errors ~~half~~ common to all Glaſs which are hereby reduced one half ~~errors~~ from the Obliquity of refraction in ſuch Angles.

Beſides the advantages already enumerated, there is one more which I think its proper to mention, and that is, you have it in your power to meaſure either to the right or left from the Object you look direct at, without Inverting the Quadrant or ſhifting it from one hand to the other, which cannot be done where the Index Glaſs is fixed in one Poſition on the Index.

Alſo in taking Altitudes from Reflecting Surfaces, ſuch as Water or Quickſilver, &c. which is called the double Altitude, you are confined by the Octant to 45 degrees, and by the Sextant to 60°, but here you may take it to 80° with great eaſe and with the Advantages of a large field, &c. as before obſerved.

Of the Adjuſtment of *the* GLASSES.

Obſerve that the Altitude, or Angle of an Object taken by this or any other Reflecting Quadrant, is determined by the Inclination of the planes or ſurfaces of the Glaſſes to each other, which has before been proved. Therefore to adjuſt the Quadrant for an obſervation, in meaſuring Angles to the right, or taking altitudes at Sea, you bring the Glaſſes parallel in their planes to each other, when the Index is ſet at the firſt O, or begining deviſion of the Quadrant at A, fig 2, Plate 1. You ſhould alſo at all times know that they are truly vertical to the plane of the Inſtrument, particularly for the Lunar obſervation, or any other that requires to be made with equal Accuracy.

The Inſtrument-makers have a certain mechanical rule or method of adjuſting the Glaſſes, which cannot well err, but as all Inſtruments (be they ever ſo well adjuſted from the maker's hands) are liable from various cauſes to alter, the ſimpleſt and moſt efficacious methods to adjuſt them true at Sea, I look on to be the moſt valuable; the following method I ſhould recommend. * Hold the Quadrant in a Horizontal poſition with the Index Glaſs near the Eye, and look nearly in a right line down it, and in ſuch a manner that you ſee the *Arch* of the Quadrant in a direct view, and by reflection from the Glaſs at the ſame time, and if they appear to join in one direct line, making the Arch a true plane, the Glaſs is fixed truly perpendicular to the plane of the Inſtrument; on the contrary, if the Arch meets bent out of a true plane either up or down, it ſhews the Glaſſes to have an inclination, and this you rectify by adjuſting the ſcrews behind the frame of the Index Glaſs C, fig 2.

The Index Glaſs being thus adjuſted, you have two other adjuſtments to make, the firſt of which is to bring the Horizon Glaſs Parallel to the plane of the Index Glaſs, when the Index is at the firſt O, at A, and hold the Inſtrument in a Vertical poſition, directing the ſight to the Sun, Moon, or Horizon; either of the two firſt, are the beſt Objects to adjuſt by, for which purpoſe there is different ſhaded Glaſſes to ſcreen the Eye, placed before the ſight Vane, Teleſcope, or Tube, which ever is uſed; thoſe ſhades may be had, placed behind the Horizon Glaſs likewiſe, if required. Now if the object ſeen by reflection, appears on one ſide or the other of the object ſeen by direct Viſion, it ſhews the Horizon Glaſs wants adjuſting to the plane of the Index Glaſs, this you do by two milled ſcrews at the back of the Inſtrument, that goes through the frame into the Braſs block, to which the ~~Index~~ Glaſs Horz is made faſt, the block reſts on two Braſs points, and is therefore eaſily adjuſted by the ſcrews, which muſt be left tight, always obſerving to tighten the one, as much as you looſen the other, again if the object by reflection, be ſeen above or below the object ſeen by direct Viſion, then the error is in the other adjuſtment, which I call the Index error; this is corrected by moving the Index Glaſs, and Horizontal plate C, to which it is ſcrewed; the plate having a central motion independant of the center on which the Index moves, the Glaſs is moved by applying the finger and thumb, to the milled edge of the plate C, which gently move up or down, till you obſerve nearly a contact, made with the direct and reflected Image through the unſilvered part of the Horizon Glaſs E, then make the plate C faſt to the Index again, by tightning the milled ſcrew D, and with the fine adjuſting ſcrew F, complete your adjuſtment, by making the direct and Reflecting Image appear as one. All thoſe adjuſting parts are extremely accurate and ready, being all done with milled ſcrews. The while you look at the object, there is alſo another very neceſſary adjuſtment, or rather a method to know that the Inſtrument is made true, and that the Index moves over the whole ſurface, in a true plane, which cannot be known in the common Octants or Sextants, where the Index Glaſs is fixed in one poſition only on the Index; for this purpoſe you adjuſt the Glaſſes as before directed, when the Index is at the firſt O at A, then looſen the Index by the ſcrew at I, and move it forward from the firſt O at A to the furtheſt O at B, and there again make it faſt by the ſcrew before mentioned; this done, you looſen the milled ſcrew D, and with your hand applyed to the milled Edge of the plate C, move back the Index Glaſs, to its firſt poſition, parallel with the Horizon Glaſs E, and here obſerve that the Image by reflection, and object by direct Viſion, keep the ſame plane they did when the Index was at the firſt O at A. By ſetting the Index at any intermidiate diviſion, you may try as many parts of the Arch between A and B, as you think neceſſary, and care being taken, the Inſtruments may be framed ſo true as to admit of no ſenſible error, or difference throughout the whole Arch, in the new braſs Octants, Quintants or Quadrants. There will be very little if any, and in thoſe I make of wood, they being framed in a particular manner, and the centers well made of Bellmetal and Steel and properly adjuſted, that it is next to impoſſible for them to err much, but if from accident or otherwiſe they ſhould be a little out of the true plane, you can here find out what the error is, and make allowance for it when you meaſure the Angular diſtance of the Sun and Moon, or Moon and Star, and I preſume it muſt ever be too ſmall to be regarded in any other obſervations.

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* This method, which I think a good one at Sea, I had from Mr. *Adams*, Maſter of the Acadamy at *Waltham-Abbey*, *Eſſex*.

The Manner of applying the Quadrant for Obſervations to be taken by the new Method, and of taking a back Obſervation, or Zenith Diſtance with it.

EVERY adjuſtment of the Glaſſes, neceſſary for the common method of obſerving, is alſo requiſite here, and is effected in the ſame manner, the only difference is, that the Index muſt now be placed to a coincidence with the firſt diviſion or (O B,) inſtead of A, before you begin thoſe Adjuſtments.

And likewiſe in meaſuring altitudes, or Angles by this method, the Index is moved towards you, and the Arch elevated, by holding it as much inclined above an Horizontal Line, as you would depreſs it below, was you to meaſure the ſame angular diſtance in a common way; if it be an Altitude, the Arch muſt be upwards, and truly vertical, alſo in all Horizontal and Oblique Angles the object ſeen by reflection is to the right, while the face of the Quadrant is upwards, as that is to the left in the common way of obſerving, on which account I before mentioned, the advantage of having it in your power to meaſure either to the right or left without the diſagreeable neceſſity of inverting the Quadrant, unleſs the Angle exceeds 90° with the Octant, or 100° in the Sextant and Quintant;

after which (to keep a larger field of view, &c.) it will be beſt to meaſure by the new method either to the right or left.

It frequently happens at Sea, that the Horizon is not ſo clear for obſerving by a direct or fore obſervation, as it is by turning your back to the Sun, and looking at the Horizon diametrically oppoſite to it. This you do with the Arch held up in a vertical poſition and looking through the ſight Vane, or Teleſcope at the Horizon. You gradually move the Index towards you from B, till you make a contact with the Sun's upper limb by reflection, and the Horizon by direct viſion, if requiſite; turn down one, two, or all the ſcreen Glaſſes at G, to ſhade the Eye, and uſe the ſame precautions in this obſervation (to know that you meaſure the altitude, or rather the exceſs of the altitude or Zenith diſtance in a true Vertical line paſſing from the Sun to the Horizon,) as you would do in making a common obſervation. This may be done by the Octant at any time, if the Sun be 15° above the Horizon, and with the Sextant and Quintant when about 25°, as the firſt will meaſure to 165°, and the two laſt to 155°.

Obſerve likewiſe that the diſtance is now meaſured from the Horizon to the Sun's upper limb, by reaſon of its exceeding 90°, from the Horizon; and on which account it is alſo inverted.

You muſt therefore ſubtract the dip of the Sea, for the Eye of the obſerver being above the level, and add the ſemi-diameter of the Sun (which on a mean is 16 minutes) to the Zenith diſtance, and add the refraction alſo.

	Min.Deg.Sec.
For example, ſuppoſe the obſerved diſtance from the Sea Horizon to the Sun's upper limb to be	145.10. 0.
From which ſubtract the dip, the eye being 27 feet above the level	0. 5. 0.
	145. 5. 0.
From the Horizon to the Zenith, 90°. which ſubtract.	90. 0. 0.
Leaves the obſerved Zenith diſtance	55. 5. 0.
To which add the Sun's Semi-diameter.	0.16. 0.
The refraction alſo add.	0. 1.21.
True Zenith diſtance.	55.22.21.
Which ſubtracted from	90. 0. 0.
Leaves the true Altitude.	34.37.39.

By this new method of uſing the Quadrant, in taking a fore and back obſervation, you get the true dip of the ſea above the level of the eye, in a moſt eaſy and exact manner, as follows:

Within about twenty minutes of 12 o'clock, take the ſun's altitude by a fore or direct obſervation from the ſun's lower limb, then immediately turn your back to the ſun, and take its diſtance from the upper limb to the horizon. Thoſe two altitudes being added to the ſun's diameter, (which on a mean is thirty two minutes), will give the quantity of the arch meaſured: from which ſubtract 180°, and the remainder will be double the dip; if you would be more exact, take the ſun's diameter from the nautical ephemiris, where it is given for every ſixth day in the month, and inſtead of taking the obſervations before noon, you may take it backwards, immediately after taking the meridian altitude for finding the latitude.

To adjuſt the Octant to meaſure Angular Diſtances from 90 *to* 165 *Degrees, by the new Method.*

I Before obſerved that the Index of the Octant would require to be twice adjuſted, before you could meaſue any diſtance exceeding 90 degrees, which is done in the following manner, you firſt bring the Index H, plate 1, fig 2, to the firſt diviſion on the Arch at B, and make a very exact coincidence with the O, or firſt diviſion of the Nonius, and that on the Arch, which done, make it faſt by the ſcrew I, and the Glaſſes parallel, (by the method before directed,) then look through the ſight Vane or Teleſcope at the Sun, Moon, or Horizon, and move the proper ſcrews till you obſerve the object you look directly at, and that ſeen by reflection appear as one, this done looſen the milled ſcrew I from the Arch, and move the Index to 90 degrees, and again make faſt the ſcrew I; you now take the milled ſcrew K, which you will find at the back of the frame oppoſite L, and put it thro' the notch in the braſs plate C, which make faſt to the frame of the Octant by ſcrewing it tight againſt a braſs piece that is faſtened by ſcrews in a ſolid manner to the frame, and looſen the ſcrew D which gives freedom, to the Index—The Index Glaſs being thus removed 90 degrees backward on the Arch, and firmly fixed by the ſcrew K, let it there remain, whilſt you remove the Index to its firſt adjuſtment at B, and faſten it again by the ſcrew I, now make faſt the ſcrew D, take away the ſcrew K, and the Octant is perfectly adjuſted for all obſervations which exceed 90 degrees; and whatever the diſtance is that you meaſure and read off from the Arch, it will be the ſupplement to 90 degrees already meaſured, by the adjuſtment.

Should the diſtance exceed 120° the ſight will require to be removed farther from the frame, to give room, for the inſident ray to fall on the Index Glaſs, which otherwiſe would be intercepted by the head of the obſerver * for which purpoſe the bar N is uſed, and has a grove cut through it, to admit of its ſliding farther or nearer the frame, as may be required, it is faſtned at pleaſure to the back of the frame by the two ſcrews K and M, in a right line paſſing from the Eye through the middle of the Horizon Glaſs E.

The ſight Vane Q, fig 9, and the adjuſting ſocket and ring S, fig 5, into which the Teleſcope or blank tube ſcrews, will either of them fit into the bar at the end R, where there is a hole to receive them when the bar is made uſe of.

To Adjuſt the Sextant, and Quintant to meaſure any Angular Diſtance from O, to 165 Degrees, by the new Method.

THIS is done in the ſame manner as before directed for the Octant, only obſerve and remove the Index to 100 degrees on the Arch, of the Sextant inſtead of 90°, and add the ſupplement to the 100.

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* This will happen with the Octant only, as the ſight is fixed in the Sextant, and Quintants at a diſtance far enough off to admit of the rays paſſing to meaſure 150, or 155°, without any interruption, although not more than 2 inches further off than common.

The Quintant is adjuſted in the ſame manner, with the index faſtened at (O B,) but having an Arch graduated to 155 degrees, will require no ſecond removal or adjuſtment in the Index, and on which account it is I think, preferable, although not quite ſo portable; but in thoſe matters people differ in opinion, the Octant and Sextant being equally as accurate as the Quintant, with a little more trouble in adjuſting them.

The Method to know that the Obſervations are made in a line, parallel with the plane of the Inſtrument; with the plain ſight, and the erect or concave Eye Glaſs Teleſcope.

THE hole to obſerve through the ſight Vane Q, fig 9. is in a ſquare peice of braſs, which ſlides up or down the flat part A, by which means you adjuſt it to any required height, and the Index being faſtened to the firſt diviſion or O at B, adjuſt the Glaſſes parallel as before directed, then looſen the ſcrew (I) behind the Arch and move the Index H toward you about 30 or between 25 and 35°, and you will obſerve the inſide of the ſight vane Q with its center hole reflected to the Eye, you now move the ſliding peice up or down, till the bottom part of the hole in the ſight appears juſt off the edge or quickſilvered part of the Horizon Glaſs, and on this part of the Glaſs you muſt make a coincidence, with the objects you meaſure, if you make uſe of the Teſcope P, the ring and ſocket S, fig 5, is firſt put into its place at W, and the ſhutter D, turned down, then adjuſt it by the ſcrew Q for the hole in the center to be the ſame height you made that in the ſight Vane Q, you then ſcrew the Teleſcope P into the ring, and obſerve that the objects meaſured are brought into the middle of the field in the Teleſcope; the ſame thing muſt be done with the inverted Teleſcope, if there is no parallel wires in the Eye-ſtop. At the Eye end of the Teleſcope is a braſs circle or wheel, with a double milled edge, which turns round on a center, in which there is one open hole and three others, that contain different ſhaded Glaſſes to ſcreen the Eye from the Sun, and alſo a green one for the Moon, you move them on or off at pleaſure by turning the wheel by the milled edge, and either Glaſs wanted will ſtop at the center hole, by the point of a ſpring falling into a ſmall hole in the wheel, on the inſide of the ſame end, in a ſmall braſs frame is ſcrewed the concave Eye Glaſs of the Teleſcope P, having a pin that projects through the plate to the outſide, by touching this pin with your thumb, or finger nail, you put the concave on or off the ſight hole as it may be wanted. This wheel of Glaſſes, I frequently put to the ſight Vane Q, the inſide tube of the Teleſcope P, has a ſcrew alſo on the further end, and is uſed as an open tube, by ſcrewing it into the ring in place of the Teleſcope, when the concave is put off from the ſight hole.

To

To take the Altitude of the Sun at Sea by a direct or fore Obſervation, with the improved Octant, Sextant, or Quintant.[*]

THE ſun is generally bright enough to be ſeen by reflection in the unſilvered part of the horizon glaſs, therefore ſlide the ſight high enough to look through that part of the glaſs: the dark glaſſes are to be uſed as the brightneſs of the ſun may require. If the reflection of the ſun's light from the ſea ſhould cauſe the horizon to appear glaring and indiſtinct, then, by turning the green glaſs in the wheel before the eye, this glare will be taken off, and the horizon will appear more diſtinct. Now hold the Octant in a vertical poſition, and direct the ſight to that part of the horizon that is under the ſun, and move the index from *(O A)* on the arch, till you ſee the image of the ſun come down nearly to the horizon; then ſwing the Octant round a line parallel to the line of ſight: by this means the image of the ſun may be made to deſcribe the arch of a circle whoſe convex ſide is downwards, without ever departing conſiderably from the middle of the tranſparant part of the horizon glaſs. Move the index till the lower edge or limb of the ſun juſt grazes the horizon, then ſtop the index by the ſcrew I at the back, and the degrees and minutes ſhewn on the arch will be the *apparant* altitude of the ſun's lower edge above the viſible horizon.

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[*] Before this or any other Altitude is taken, obſerve that the glaſſes are adjuſted, (as before directed), when the index is at the firſt (O. A.), and the inſtrument muſt be held in a vertical poſition, with the arch downwards, as is commonly done.

This altitude requires three different corrections before the true altitude of the ſun's center above the real horizon can be obtained.

First Correction. *Add* 16 minutes for the ſun's ſemi-diameter; by this you have the apparent altitude of its center above the viſible horizon.

Second Correction. *Subtract* the dip of the horizon (which is occaſioned by the height of the obſerver's eye above the ſurface of the water) according to the following table.

The eye above the ſurface of the ſea in feet.	*Depreſſion, or dip of the viſible horizon, in minutes.*
1	1
4	2
10	3
17	4
27	5
39	6
53	7

Third Correction. This is neceſſary on account of the refraction of the atmoſphere. For the rays of the ſun, and of all other celeſtial objects, falling obliquely on the earth's atmoſphere, are more or leſs refracted, according to the degree of obliquity with which they enter; that is, according to the altitude of the object. Hence all celeſtial objects appear higher than they really are. At the end, is given *a Table of Refractions*, corrected according to the lateſt obſervations. This table is made for every intire degree of apparent altitude, which is as near as is neceſſary. It ſhews how many minutes and ſeconds are to be *ſubtracted* from the apparent altitude on account of refractions. By theſe three corrections you will obtain the true altitude of the ſun's center above the real horizon.

Example.

	deg.	min.
Suppoſe the obſerved altitude to be —	34	10
Firſt correction the ſun's diameter *add* —	0	16
	34	26
Second correction. The dip of the horizon for 27 feet, the ſuppoſed height of the obſerver's eye above the water, *ſubtract* — —	0	5
	34	21
Third correction. For the refraction *ſubtract*	0	1
Remains the ſun's true altitude —	34	20
To obtain the true zenith diſtance *ſubtract* the true altitude from — —	90	0
Remains the ſun's zenith diſtance — —	55	40

To take the Altitude of a Star by the direct or fore Obſervation.

SET the index at (O A) on the arch, and holding the plane of the Octant vertical, direct the ſight to the ſtar; at the ſame time look for the reflected image of the ſtar in the ſilvered part of the horizon glaſs: move the index a little, which will ſeparate the reflected image ſeen by direct viſion; the former will be eaſily diſtinguiſhed from the latter by its motion, when you begin to move the Index, which continue to move foreward, and at the ſame time follow the reflected image of the ſtar with your eye, directing the ſight lower and lower, and changing the poſition of the Octant as the ſtar deſcends, till you have brought it down to the horizon; the index will then ſhew the obſerved altitude of the ſtar. It is neceſſary always to keep ſight of the reflected image of the ſtar that you may not miſtake the image of ſome other ſtar for the image of that whoſe altitude you would take. But if the altitude is known nearly, you may ſet the index at firſt to that altitude, and holding the Octant verticle, direct the ſight to the part of the horizon juſt under the ſtar, and you will find the reflected image near the horizon. By moving the index a little you may bring it to touch as before.

There are only two corrections to be made to the obſerved altitude of a ſtar; the dip of the horizon and the refraction; for the fixed ſtars have no viſible diameter.

Rules for finding the Latitude from the Sun's Zenith Diſtance and Declination at Noon given.

THE ſun's declenſion admits of two denominations; that is, north and ſouth. So likewiſe does the ſun's zenith diſtance, for the ſun comes to the meridian either northward or ſouthward of the zenith. The latitude alſo admits of the ſame variation in its denomination. This being premiſed, the following rules will be eaſily underſtood.

Rule I. If the zenith diſtance and declination are of different denominations, their ſum will give the latitude, whoſe denomination will be the ſame as that of the declination.

Rule II. If the zenith diſtance and declination are both of the ſame denomination, their difference will give the latitude, whoſe denomination will be the ſame with that of the zenith diſtance and declination, if the declination is greater than the zenith diſtance. But if the zenith diſtance is greateſt, the latitude will be of a contrary denomination.

The two following rules ſerve to find the latitude of the place from the altitude and declination at noon given.

Rule III. If the altitude and declination are of different denominations, add 90 degrees to the declination, and from that ſum ſubtract the altitude; the remainder is the latitude, and is of the ſame denomination as the declination.

RULE IV. If the altitude and declination are of a like denomination, add the declination to the altitude, and ſubtract that ſum from 90 degrees; if it be leſs, the remainder will be the latitude, and it will be of a contrary denomination. But if it exceeds 90 degrees, the exceſs will be the latitude, whoſe denomination will be the ſame as that of the altitude and declination.

A TABLE *of* REFRACTIONS *to be ſubtracted from the Apparent Altitudes, and added to the Zenith Diſtances.*

Alt	Refract.		Alt	Refract.		Alt	Refract.		Alt	Refract.		Alt	Refract.	
d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.	d.	min.	ſec.
½	27													
1	24	29	19	2	44	37	1	16	55	0	40	73	0	17
2	18	35	20	2	35	38	1	13	56	0	38	74	0	16
3	14	36	21	2	27	39	1	10	57	0	37	75	0	15
4	11	51	22	2	20	40	1	8	58	0	35	76	0	14
5	9	54	23	2	14	41	1	5	59	0	34	77	0	13
6	8	28	24	2	7	42	1	3	60	0	33	78	0	12
7	7	20	25	2	2	43	1	1	61	0	32	79	0	11
8	6	29	26	1	56	44	0	59	62	0	30	80	0	10
9	5	48	27	1	51	45	0	57	63	0	29	81	0	9
10	5	15	28	1	47	46	0	55	64	0	28	82	0	8
11	4	47	29	1	42	47	0	53	65	0	26	83	0	7
12	4	23	30	1	38	48	0	51	66	0	25	84	0	6
13	4	3	31	1	35	49	0	49	67	0	24	85	0	5
14	3	45	32	1	31	50	0	48	68	0	23	86	0	4
15	3	30	33	1	28	51	0	46	69	0	22	87	0	3
16	3	17	34	1	24	52	0	44	70	0	21	88	0	2
17	3	4	35	1	21	53	0	43	71	0	19	89	0	1
18	2	54	36	1	18	54	0	41	72	0	18	90	0	0

A TABLE *of the Sun's Declination, for the* FIRST *Year after* LEAP *Year.*

	S.	S.	S.	N.	N.	N.	N.	N.	N.	S.	S.	S.
Days	Jan.	Feb.	Mar.	April	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	d. m.	d, m	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.	d. m.
1	23 00	16 54	7 24	4 43	15 13	22 8	23 8	17 59	8 10	3 20	14 36	21 55
2	22 54	16 41	7 1	5 6	15 31	22 16	23 4	17 44	7 49	3 44	14 55	22 4
3	22 48	16 23	6 38	5 29	15 48	22 23	22 59	17 28	7 27	4 7	15 14	22 13
4	22 42	16 5	6 15	5 52	16 5	22 30	22 54	17 12	7 5	4 30	15 33	22 21
5	22 35	15 46	5 52	6 15	16 23	22 37	22 48	16 56	6 42	4 54	15 51	22 29
6	22 28	15 28	5 29	6 37	16 40	22 43	22 42	16 39	6 20	5 17	16 9	22 36
7	22 20	15 10	5 6	7 0	16 56	22 49	22 36	16 22	5 57	5 40	16 27	22 43
8	22 12	14 51	4 42	7 22	17 13	22 55	22 29	16 5	5 35	6 3	16 44	22 49
9	22 4	14 31	4 19	7 45	17 29	23 0	22 22	15 48	5 12	6 26	17 1	22 55
10	21 55	14 12	3 55	8 7	17 44	23 5	22 15	15 31	4 49	6 48	17 18	23 0
11	21 45	13 52	3 32	8 29	18 0	23 9	22 7	15 13	4 26	7 11	17 35	23 5
12	21 35	13 32	3 8	8 51	18 15	23 13	21 58	14 55	4 3	7 34	17 51	23 10
13	21 25	13 12	2 44	9 13	18 30	23 16	21 50	14 36	3 40	7 56	18 7	23 14
14	21 14	12 51	2 21	9 34	18 44	23 19	21 41	14 18	3 17	8 19	18 23	23 17
15	21 3	12 31	1 57	9 55	18 59	23 22	21 31	13 59	2 54	8 41	18 38	23 20
16	20 52	12 11	1 33	10 17	19 13	23 24	21 22	13 40	2 31	9 3	18 53	23 23
17	20 40	11 50	1 10	10 38	19 26	23 26	21 11	13 21	2 7	9 25	19 8	23 25
18	20 28	11 28	0 46	10 59	19 39	23 27	21 1	13 2	1 44	9 47	19 23	23 27
19	20 15	11 6	0 22	11 20	19 52	23 28	20 50	12 42	1 21	10 9	99 37	23 28
			N									
20	20 2	10 45	0 1	11 40	20 5	23 29	20 38	12 22	0 57	10 31	19 50	23 29
21	19 49	10 23	0 25	12 1	20 17	23 29	20 27	12 2	0 34	10 52	20 4	23 29
22	19 35	10 1	0 49	12 21	20 29	23 29	20 15	11 42	0 11	11 13	20 17	23 29
									S			
23	19 21	9 39	1 12	12 41	20 41	23 28	20 3	11 22	0 13	11 34	20 29	23 28
24	19 6	9 17	1 36	13 1	20 52	23 27	19 51	11 1	0 36	11 55	20 41	23 27
25	18 50	8 55	2 0	13 20	21 3	23 26	19 38	10 41	1 0	12 16	20 53	23 25
26	18 36	8 32	2 23	13 39	21 13	23 24	19 25	10 19	1 23	12 37	21 4	23 23
27	18 21	8 10	2 47	13 59	21 23	23 21	19 11	9 58	1 46	12 57	21 15	23 21
28	18 5	7 47	3 10	14 18	21 33	23 19	18 57	9 37	2 10	13 17	21 26	23 18
29	17 49		3 33	14 36	21 42	23 15	18 43	9 16	2 33	13 37	21 36	23 14
30	17 32		3 57	14 55	21 51	23 12	18 29	8 54	2 56	13 57	21 46	23 10
31	17 15		4 20		22 0		18 16	8 32		14 17		23 6

A TABLE

A TABLE *of the Sun's Declination, for the* SECOND *Year after* LEAP *Year.*

	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
Days	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m	d.	m.	d.	m.	d	m.	d.	m.	d.	m.	d.	m.
1	23	1	17	3	7	30	4	37	15	8	22	6	23	8	18	2	8	15	3	15	14	31	21	54
2	22	55	16	45	7	7	5	0	15	26	22	14	23	[illegible]	17	47	7	54	3	38	14	50	22	3
3	22	49	16	27	6	44	5	23	15	44	22	22	22	59	17	31	7	32	4	2	15	9	22	12
4	22	43	16	10	6	21	5	46	16	1	22	20	22	54	17	15	7	10	4	25	15	28	22	20
5	22	37	15	52	5	58	6	9	16	18	22	36	22	49	16	59	6	47	4	48	15	47	22	27
6	22	30	15	33	5	34	6	32	16	35	22	43	22	43	16	45	6	25	5	11	16	5	22	34
7	22	23	15	14	5	10	6	54	16	52	22	49	22	37	16	27	6	2	5	34	16	23	22	41
8	22	15	14	55	4	46	7	17	17	9	22	54	22	30	16	10	5	39	5	57	16	41	22	48
9	22	6	14	36	4	23	7	39	17	25	22	59	22	23	15	53	5	17	6	20	16	58	22	54
10	21	57	14	16	4	0	8	1	17	41	23	4	22	16	15	35	4	54	6	43	17	15	23	0
11	21	48	13	57	3	37	8	23	17	56	23	8	22	8	15	17	4	32	7	5	17	32	23	5
12	21	38	13	37	3	14	8	45	18	11	23	12	22	0	14	59	4	9	7	28	17	48	23	10
13	21	28	13	17	2	50	9	7	18	26	23	15	21	52	14	41	3	46	7	50	18	4	23	14
14	21	17	12	57	2	26	9	29	18	41	23	18	21	43	14	23	3	23	8	13	18	20	23	17
15	21	6	12	36	2	3	9	50	18	56	23	21	21	34	14	4	3	0	8	35	18	35	23	20
16	20	55	12	15	1	40	10	11	19	10	23	23	21	24	13	45	2	37	8	57	18	50	23	23
17	20	43	11	54	1	16	10	32	19	24	23	25	21	14	13	26	2	14	9	19	19	5	23	25
18	20	31	11	33	0	52	10	53	19	37	23	27	21	4	13	7	1	50	9	41	19	19	23	27
19	20	18	11	11	0	28	11	14	19	50	23	28	20	53	12	47	1	27	10	3	19	33	23	28
20	20	5	10	49	0	5	11	35	20	2	23	29	20	42	12	27	1	3	10	25	19	47	23	29
					N																			
21	19	52	10	28	0	19	11	55	20	14	23	29	20	30	12	7	0	39	10	47	20	0	23	29
22	19	38	10	7	0	43	12	15	20	26	23	29	20	18	11	47	0	16	11	8	20	13	23	29
																	S							
23	19	24	9	35	1	6	12	35	20	38	23	28	20	6	11	27	0	8	11	29	20	26	23	28
24	19	10	9	23	1	30	12	55	20	50	23	27	19	54	11	6	0	31	11	50	20	38	23	27
25	18	55	9	0	1	53	13	15	21	1	23	26	19	41	10	45	0	54	12	11	20	50	23	26
26	18	40	8	38	2	17	13	34	21	11	23	24	19	28	18	2	1	17	12	34	21	2	23	24
27	18	25	8	15	2	40	13	53	21	21	23	21	19	15	18	3	1	40	12	53	21	13	23	21
28	18	9	7	53	3	4	14	12	21	31	23	18	19	1	9	42	2	4	13	12	21	24	23	18
29	17	53			3	27	14	31	21	40	23	15	18	47	9	20	2	28	13	32	21	34	23	15
30	17	37			3	51	14	50	21	49	23	12	18	33	8	58	2	52	13	52	21	44	23	11
31	17	10			4	14			21	58			18	18	8	36			14	12			23	7

A TABLE

A TABLE *of the Sun's Declination, for the* THIRD *Year after* LEAP *Year.*

	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
Days	Jan.		Feb.		Mar.		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m	d.	m.	d.	m.	d.	m.
1	23	2	17	6	7	36	4	31	15	4	22	4	23	9	18	6	8	22	3	8	14	26	21	52
2	22	57	16	49	7	13	4	54	15	22	22	12	23	5	17	51	8	0	3	32	14	46	22	1
3	22	51	16	31	6	50	5	17	15	40	22	20	23	1	17	35	7	38	3	55	15	5	22	9
4	22	45	16	14	6	27	5	40	15	58	22	27	22	56	17	19	7	16	4	18	15	24	22	17
5	22	39	15	56	6	3	6	3	16	15	22	34	22	50	17	4	6	54	4	41	15	42	22	25
6	22	32	15	38	5	40	6	26	16	32	22	40	22	44	16	48	6	32	5	4	16	0	22	32
7	22	24	15	19	5	17	6	48	16	49	22	46	22	38	16	31	6	9	5	21	16	18	22	39
8	22	16	15	0	4	54	7	10	17	5	22	52	22	32	16	14	5	46	5	52	16	36	22	45
9	22	8	14	41	4	30	7	33	17	21	22	57	22	25	15	57	5	23	6	13	16	54	22	51
10	21	59	14	22	4	7	7	56	17	37	23	2	22	18	15	39	5	0	6	36	17	11	22	57
11	21	50	14	2	3	43	8	18	17	52	23	7	22	10	15	21	4	38	6	59	17	28	23	2
12	21	40	13	42	3	20	8	40	18	7	23	11	22	2	15	3	4	15	7	22	17	44	23	7
13	21	30	13	22	3	56	9	2	18	22	23	14	21	54	14	45	3	52	7	44	18	0	23	11
14	21	20	13	2	2	32	9	23	18	37	23	18	21	45	14	27	3	29	8	7	18	16	23	15
15	21	9	12	42	2	8	9	45	18	52	23	21	21	35	14	9	3	6	8	30	18	32	22	18
16	20	58	12	21	1	45	10	7	19	6	23	23	21	26	13	50	2	43	8	52	18	47	23	21
17	20	46	12	0	1	21	10	28	19	20	23	25	21	16	13	31	2	19	9	14	19	1	23	24
18	20	34	11	39	0	57	10	49	19	34	23	27	21	5	13	11	1	56	9	36	19	16	23	26
19	20	21	11	18	0	34	11	10	19	47	23	28	20	54	12	51	1	33	9	58	19	30	23	27
20	20	9	10	56	0	10	11	30	20	0	23	29	20	43	12	32	1	9	10	20	19	44	23	28
					N																			
21	19	56	10	34	0	14	11	50	20	12	23	29	20	32	12	12	0	45	10	42	19	57	23	29
22	19	42	10	12	0	37	12	10	20	24	23	29	20	21	11	52	0	22	11	4	20	10	23	29
																	S							
23	19	28	9	50	1	1	12	30	20	36	23	28	20	10	11	32	0	1	11	25	20	23	23	28
24	19	14	9	28	1	24	12	50	20	47	23	28	19	58	11	12	0	25	11	45	20	35	23	27
25	18	59	9	6	1	48	13	10	20	58	23	27	19	45	10	51	0	48	12	5	20	47	23	26
26	18	44	8	44	2	12	13	29	21	9	23	25	19	31	10	30	1	12	12	26	20	59	23	24
27	18	29	8	21	2	35	13	48	21	19	23	23	19	18	10	9	1	35	12	47	21	10	23	22
28	18	13	7	58	2	58	14	7	21	29	23	20	19	4	9	48	1	59	13	7	21	21	23	19
29	17	56			3	22	14	26	21	38	23	17	18	50	9	27	2	22	13	27	21	31	23	16
30	17	40			3	45	14	45	21	47	23	14	18	36	9	4	2	45	13	47	21	42	23	13
31	17	23			4	8			21	56			18	21	8	43			14	7			23	9

A TABLE *of the Sun's Declination, for* LEAP *Year.*

	S.		S.		S.		N.		N.		N.		N.		N.		N.		S.		S.		S.	
Days	Jan.		Feb.		March		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d,	m.	d.	m.	d.	m.
1	23	3	17	11	7	18	4	49	15	17	22	10	23	7	17	55	8	5	3	27	14	41	21	58
2	22	58	16	54	6	55	5	12	15	34	22	18	23	3	17	40	7	43	3	50	15	0	22	7
3	22	52	16	36	6	32	5	35	15	52	22	25	22	58	17	24	7	21	4	13	15	19	22	15
4	22	46	16	18	6	9	5	57	16	10	22	32	22	52	17	8	6	59	4	36	15	37	22	23
5	22	40	16	0	5	46	6	20	16	27	22	39	22	47	16	52	6	37	4	59	15	55	22	30
6	22	33	15	42	5	23	6	43	16	44	22	45	22	41	16	35	6	14	5	22	16	13	22	37
7	22	26	15	24	4	59	7	5	17	0	22	51	22	34	16	18	5	52	5	45	16	31	22	48
8	22	18	15	5	4	36	7	27	17	17	22	56	22	27	16	1	5	29	6	8	16	49	22	50
9	22	10	14	46	4	13	7	50	17	33	23	1	22	20	15	44	5	6	6	31	17	6	22	56
10	22	1	14	27	3	49	8	12	17	48	23	6	22	13	15	26	4	44	6	54	17	23	23	1
11	21	52	14	7	3	26	8	34	18	4	23	10	22	5	15	8	4	21	7	17	17	39	23	6
12	21	42	13	47	3	2	8	56	18	19	23	14	21	56	14	51	3	57	7	39	17	55	23	11
13	21	33	13	27	2	38	9	18	18	34	23	17	21	47	14	33	3	34	8	2	18	11	23	15
14	21	23	13	7	2	15	9	39	18	48	23	20	21	38	14	14	3	11	8	24	18	27	23	18
15	21	12	12	46	1	51	10	0	19	2	23	22	21	29	13	55	2	48	8	47	18	42	23	21
16	21	1	12	26	1	28	10	21	19	16	23	24	21	19	13	36	2	25	9	9	18	57	23	23
17	20	49	12	5	1	4	10	42	19	29	23	26	21	9	13	16	2	2	9	31	19	12	23	25
18	20	37	11	43	0	40	11	3	19	42	23	28	20	58	12	57	1	38	9	53	19	26	23	27
19	20	25	11	22	0	16	11	24	19	55	23	28	20	47	12	37	1	15	10	14	19	40	23	28
					N																			
20	20	12	11	1	0	7	11	45	20	8	23	29	20	36	12	17	0	52	10	36	19	54	23	29
21	19	59	10	40	0	31	12	5	20	20	23	29	20	25	11	57	0	29	10	57	20	7	23	29
22	19	45	10	18	0	55	12	26	20	32	23	29	20	13	11	37	0	5	11	19	20	20	23	29
																	S							
23	19	31	9	56	1	18	12	45	20	43	23	28	20	0	11	17	0	19	11	40	20	32	23	28
24	19	17	9	34	1	41	13	5	20	54	23	27	19	48	10	56	0	42	12	1	20	44	23	27
25	19	3	9	12	2	5	13	25	21	5	23	25	19	35	10	35	1	6	12	21	20	56	23	25
26	18	48	8	49	2	29	13	44	21	15	23	23	19	21	10	14	1	29	12	42	21	7	23	22
27	18	32	8	27	2	52	14	3	21	25	23	20	19	8	9	53	1	53	13	2	21	18	23	19
28	18	17	8	4	3	15	14	22	21	35	23	18	18	54	9	32	2	16	13	22	21	29	23	16
29	18	1	7	41	3	39	14	41	21	44	23	15	18	40	9	11	2	39	13	42	21	39	23	13
30	17	45			4	2	14	59	21	53	23	11	18	25	8	49	3	3	14	2	21	48	23	9
31	17	18			4	25			22	2			18	10	8	27			14	22			23	5

A TABLE *of the Equation of Time.*

Days	Jan. Add.	Feb. Add.	March Add.	April Add.	May Sub.	June Sub·	July Add.	Aug. Add.	Sept. Sub.	Oct. Sub.	Nov. Sub.	Dec. Sub.
	m. ſ.	m. ſ.	m. ſ.	m. ſ.	m. ſ.	m. ſ,	m. ſ.	m. ſ.	m. ſ.	m. ſ.	m. ſ.	m. ſ.
1	4 14	14 6	12 37	3 51	3 10	2 37	3 20	5 51	0 19	10 27	16 14	10 29
2	4 42	14 13	12 24	3 33	3 17	2 28	3 31	5 48	0 38	10 45	16 14	10 6
3	5 10	14 20	12 11	3 15	3 24	2 19	3 42	5 43	0 57	11 4	16 14	9 41
4	5 37	14 25	11 57	2 57	3 30	2 9	3 53	5 38	1 16	11 22	16 12	9 17
5	6 4	14 29	11 43	2 39	3 36	1 58	4 4	5 32	1 36	11 39	16 10	8 52
6	6 31	14 33	11 29	2 21	3 41	1 48	4 14	5 26	1 55	11 56	16 7	8 26
7	6 57	14 36	11 14	2 4	3 45	1 37	4 24	5 20	2 15	12 13	16 4	7 59
8	7 22	14 38	10 59	1 47	3 49	1 26	4 33	5 12	2 35	12 30	15 59	7 33
9	7 47	14 40	10 44	1 30	3 52	1 14	4 43	5 4	2 56	12 46	15 54	7 6
10	8 11	14 40	10 28	1 13	3 55	1 2	4 51	4 56	3 16	13 1	15 47	6 38
11	8 35	14 40	10 11	0 57	3 57	0 50	5 0	4 47	3 37	13 16	15 40	6 10
12	8 58	14 39	9 55	0 41	3 59	0 38	5 8	4 37	3 57	13 31	15 32	5 42
13	9 21	14 38	9 38	0 25	4 0	0 25	5 15	4 27	4 18	13 45	15 24	5 13
14	9 43	14 35	9 21	0 10	4 0	0 13	5 22	4 16	4 39	13 58	15 14	4 44
15	10 4	14 32	9 4	Sub. 4	4 0	0 0	5 28	4 5	5 0	14 11	15 4	4 15
16	10 25	14 28	8 47	0 19	3 59	Ad. 12	5 34	3 53	5 21	14 24	14 52	3 46
17	10 44	14 24	8 29	0 33	3 58	0 25	5 40	3 41	5 42	14 36	14 40	3 17
18	11 3	14 18	8 11	0 47	3 56	0 38	5 45	3 28	6 3	14 47	14 28	2 47
19	11 22	14 12	7 53	1 1	3 54	0 51	5 49	3 14	6 24	14 58	14 14	2 17
20	11 39	14 5	7 35	1 14	3 51	1 3	5 53	3 0	6 45	15 8	13 59	1 47
21	11 56	13 58	7 17	1 27	3 47	1 16	5 56	2 46	7 6	15 18	13 44	1 17
22	12 12	13 50	6 58	1 40	3 43	1 29	5 58	2 31	7 27	15 26	13 28	0 47
23	12 27	13 41	6 40	1 52	3 39	1 42	6 0	2 16	7 48	15 34	13 11	0 17
24	12 42	13 32	6 21	2 3	3 34	1 55	6 2	2 0	8 9	15 42	13 54	Ad. 12
25	12 55	13 22	6 2	2 14	3 29	2 7	6 2	1 44	8 29	15 48	12 35	0 42
26	13 8	13 11	5 43	2 24	3 23	2 20	6 2	1 27	8 49	15 54	12 16	1 12
27	13 20	13 0	5 25	2 34	3 16	2 32	6 2	1 10	9 9	16 0	11 56	1 41
28	13 31	12 49	5 6	2 44	3 9	2 44	6 1	0 53	9 29	16 4	11 35	2 11
29	13 41		4 47	2 53	3 2	2 56	6 0	0 35	9 49	16 8	11 14	2 40
30	13 50		4 28	3 2	2 54	3 8	5 58	0 17	10 8	16 11	10 52	3 9
31	13 59		4 10		2 46		5 55	Sub 0		16 13		3 38

In the above Table, you have the number of Minutes and Seconds (for every day throughout the year) to be added to, or ſubtracted from Solar Time, to ſhew Equated, or Mean Time, which is that always ſhewn by a good clock or watch.

DIRECTIONS

FOR USING THE

OCTANT, SEXTANT AND QUINTANT

TO DETERMINE THE

LONGITUDE AT SEA.

THE uſe of this inſtrument in determining the longitude at ſea, is, to obſerve the angular diſtances of the ſun and moon, or the diſtances of the moon from ſome of the principal fixed ſtars. It often happens that the diſtances of the moon from ſuch of the ſtars as are the moſt proper for theſe obſervations exceed 90 degrees, and the ſun and moon 120 degrees: for this reaſon it is, that the inſtrument intended for this purpoſe I have enlarged to the fifth part of a circle, that angles may be taken by the fore obſervation *only* as far as 155 degrees.

The Octant, as repreſented in fig. 2. plate 1, is furniſhed with all the parts for adjuſting the glaſſes, as before deſcribed, and the arch is divided forward and backward to 90 degrees, the Sextant is ſimilar, but extended in the arch to 120 degrees.

The arch B. A. in the Quintant, is divided into 155 degrees; each degree is divided into three parts, and by the vernier diviſions it is ſubdivided to every minute. *

Fig. 3. repreſents the ſmall portable ones of 4 or 6 inch radius, and divided on the Shamfoord edge, being made all of braſs, and each degree divided into two parts, the vernier into 29 or 31 each way, which ſub-divides the whole into a ſingle minute of a degree.

The principal index H, that carries the vernier diviſions along the arch, may be made faſt to it at any part by the tightening ſcrew at the back I. When this index is to be moved any conſiderable quantity, the ſcrew muſt be releaſed, and when the index is brought nearly to the diviſion required for the obſervation, the ſcrew at the back muſt be made tight; then, by turning the ſcrew X, called the *adjuſting ſcrew*, the index will be moved ſlowly along the arch, ſo that the obſervation may be made with the greater exactneſs.

The telleſcope T, which magnifies about four or five times, is uſed inſtead of a common ſight; the object being magnified a little, appears more diſtinct, and, by ſliding the tube that contains the eye glaſſes in the inſide of the other tube, the object is made to appear diſtinct to different eyes. It is ſcrewed into the circular ring S, fig. 5. by either of the ſcrews *a* or *b*, as may be found moſt convenient.

The part that ſupports the teleſcope, is repreſented at fig. 5; the upper part is the circular ring into which the teleſcope is to be ſcrewed.

This part is ſo contrived that it may be removed from the frame to the hole at *R*, fig. 4. (when it is uſed with the Octant. The ſcrews *b b* go through the ring into which the teleſcope is ſcrewed, and draw it againſt two pins fixed to the under ring at the ſides *c c*.

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* Thoſe made of a larger Radius in braſs, or with braſs arches, will admit of being divided into 30 ſeconds if required, being all divided by Mr. Ramſden, or Mr. Troughton's machines.

By looſening one of the ſcrews, and tightening the other, the teleſcope may be adjuſted parallel to the plane of the inſtrument; the method of knowing when it is ſo, will be deſcribed hereafter. By means of the ſcrew *a*, the teleſcope is moved nearer to, or farther from, the plane of the inſtrument, that it may be directed either to the ſilvered or to the unſilvered part of the glaſſes.

The parts of the horizon-glaſſes next the plane of the inſtrument are ſilvered, and the part of the Index-glaſs next the plane of the inſtrument is alſo ſilvered; but the extent of the ſilvered part of the index-glaſs exceeds the extent of the ſilvered part of the horizon-glaſſes as much as is the diameter of the aperture of the object-glaſs of the teleſcope; the remaining part of the index-glaſs is made black at the back, * that the light may be reflected from the outer ſurface only. By this method of ſilvering the glaſſes, the obſervation may be made *three* different ways, according to the difference of the brightneſs of the two objects whoſe angular diſtance is to be meaſured.

Firſt, if the object to be ſeen by reflection be obſcure, move the teleſcope as near as you can to the plane of the inſtrument, by turning the ſcrew *a* more than one half of the aperture of the object glaſs of the teleſcope will then be directed to the ſilvered part of the horizon glaſs; and the image of the object will be ſeen in the ſilvered part of the horizon-glaſs reflected from the ſilvered part of the index-glaſs. *Secondly*, if the object be bright enough to be ſeen in the unſilvered part of the horizon-glaſs, move the teleſcope by turning the ſcrew *a* till the whole aperture is directed to the unſilvered part of that glaſs, ſo as to be juſt clear of the ſilvered edge, and the image of the object will then be ſeen in the unſilvered part of the horizon-glaſs, but reflected from the ſilvered part of the index-glaſs. *Thirdly*, if the object be ſtill brighter, move the teleſcope as far from the plane of the Sextant as the ſcrew will admit, and the image of the object will then be ſeen in the unſilvered part of the horizon-glaſs, and alſo reflected from the unſilvered part of the index-glaſs.

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* This is not done in the Octants, and ſeldom in the Sextants or Quintants, unleſs particularly ordered, ſome obſervers objecting to it.

If you uſe the tube, it is to be applied in the ſame manner as the teleſcope, to direct the ſight in a line parallel to the plane of the inſtrument. It may be uſed at ſea when the weather is rough, or for taking the angular diſtances of land objects; for which purpoſe it will ſometimes be found more convenient than the teleſcope.

Fig. 10. is a frame that holds a magnifying-glaſs to aſſiſt the ſight in reading off the diviſions on the arch. The bent part goes into the ſocket *k*, on the index H Fig. 3. The reſt of the proceſs of making the adjuſtments of the glaſſes of the Octant, Sextant and Quintant having been already deſcribed, it need only to be obſerved, that the moon, or any of the brighter ſtars may be uſed for that purpoſe, and the adjuſtment may be made with more eaſe, and perhaps with more exactneſs, by the moon, planet or bright ſtar, than by the ſun.

If you have any doubts that your inſtrument is not quite accurately adjuſted, make uſe of the following method, after you have made your obſervation, and read it off.

To find the Error in the Adjuſtment, called the Index Error.

TAKE the diameter of the ſun or moon by moving the index forward; and alſo take this diameter by moving the index backwards. If the numbers ſhewn on the arch be the ſame in both caſes, the glaſſes are then truly adjuſted. If the numbers be different, then half their difference is the index error. If the diameter taken in moving the index forward, exceeds the diameter taken in moving the index backwards, then the half difference is to be ſubtracted, if the contrary, to be added. Several obſervations of the ſun's diameter being made in this manner, and a mean of the whole being taken, the index error may be found by this method to a very great exactneſs.

The nearer the ſight is directed in a line parallel to the plane of the inſtrument in making the obſervations, the more exact will thoſe obſervations be. For this reaſon there are two wires fixed parallel to each other, at the focus of the eye-glaſs, in the eye-tube of the teleſcope, by which the field of view is divided into three parts; when an obſervation is to be made, the wires muſt be ſet parallel to the plane of the inſtrument, by turning the eye-tube round, and the image of the object ſeen by reflection ſhould be brought into contact with the object ſeen by direct viſion between theſe wires, and as near to an imaginary line in the middle between them as may be. *

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* Moſt of the teleſcopes are left without the wires unleſs ordered, they can only be added to the convex eye-glaſs, or inverted teleſcopes.

To adjuſt the Teleſcope with the Wires in the Eye Stop, parallel to the Plane of the Inſtrument.

CHUSE any two diſtant objects, whoſe angular diſtance is not leſs than 90 degrees. The ſun and moon are the moſt proper objects to be uſed at ſea for this purpoſe. Bring their neareſt limbs into contact at the wire neareſt to the plane of the Inſtrument; then, by altering the poſition of the Inſtrument a little, bring them to the wire furtheſt from the plane of the Inſtrument. If their neareſt limbs be in contact as before, the teleſcope is properly adjuſted; but if the limbs of the ſun and moon lap over one another when they are brought to the wire furtheſt from the plane of the inſtrument, it ſhews the object end of the teleſcope to be inclined *from* the plane of the inſtrument. To rectify this, unſcrew the loweſt of the two ſcrews *b b* of the ring into which the teleſcope is ſcrewed, as ſhewn in fig. 5. and tighten the higheſt of thoſe ſcrews. If the neareſt limbs of the ſun and moon do not come in contact when they are brought to the wire furtheſt from the plane of the inſtrument, it ſhews the object end of the teleſcope to be inclined *towards* the plane of the inſtrument; in this caſe unſcrew the higheſt of the two ſcrews *b b*, and tighten the loweſt. By repeating this operation a few times, the teleſcope may be properly adjuſted.

To take the Altitude of the Moon at Sea by the fore or direct Obſervation.

THE ſame method is to be uſed in taking the altitude of the moon as in taking the altitude of the ſun, only it muſt be obſerved that the enlightened edge, or that edge which is round and well defined, muſt be brought into contact with the horizon, whether it be the upper or the under edge *. The moon is generally bright enough to be ſeen by reflection from the unſilvered part of the glaſſes; if not, the teleſcope muſt be moved nearer to the plane of the inſtrument.

The obſerved altitude of the moon requires four different corrections before the true altitude of her center above the real horizon can be obtained.

First Correction. The ſemi-diameter. To be found page 7 of every month in the Nautical Almanack, for every noon and midnight at Greenwich. If the lower limb was obſerved, *add* the ſemi-diameter thus found; if the upper limb was obſerved, *ſubtract* it.

Second Correction. The dip of the horizon. To be *ſubtracted.*

Third Correction. The refraction to be *ſubtracted.*

Fourth Correction. The moon's *parallax* in altitude. To be found from the requiſite tables to the Nautical Almanack, to be *added.*

Theſe four corrections being applied to the obſerved altitude of the moon, the true altitude of her center above the real horizon will be obtained.

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* If the teleſcope be of that kind that ſhews objects inverted, then the upper edge or limb of the moon will appear the lower, and the left ſide will appear at the right, and the contrary.

To take the Diſtance of the Moon from the Sun, by a direct or fore Obſervation, in order to determine the Longitude at Sea.

IN the Nautical Almanack you may find the central diſtances of the ſun and moon calculated for every three hours at Greenwich, as far as 120°. from the diſtances thus found, compute roughly the diſtance between their neareſt limbs at the time of obſervation, as directed in the Nautical Almanack.

Set the index to the diſtance of the neareſt limbs of the ſun and moon ſo found. If the ſun be to the left hand of the moon, the inſtrument muſt be adjuſted to the firſt diviſion (at B,) and the index brought towards the eye of the obſerver, as before mentioned, and held with the face upwards; but if the ſun be to the right hand of the moon, it muſt be adjuſted at the firſt diviſion (at A,) as common. Direct the teleſcope to the moon, and put the inſtrument into ſuch a poſition, that if you look edgeways againſt it, it may ſeem to make a line paſſing through the ſun and moon; then, by giving the inſtrument a ſweep, or ſwinging it round a line parallel to the line of ſight, the reflected image of the ſun will paſs by the moon, and ſo near that you cannot miſs ſeeing it. Their neareſt limbs muſt be brought into exact contact by moving the index with the adjuſting ſcrew X, ſo that giving the inſtrument the motion round the line of ſight, the reflected image of the ſun in paſſing by the moon may juſt touch her neareſt limb, which is always round and well defined. The wires in the teleſcope (if any) muſt be turned, parallel to the plane of the ſextant, and the contact muſt be made in the middle between them as before deſcribed. The obſervation being made with care according to the foregoing directions, the diviſions on the arch will ſhew the *apparent* diſtance of the neareſt limbs of the ſun and moon. This diſtance requires two corrections to obtain the *true* diſtance of their centers as ſeen from the center of the earth.

First Correction. The ſum of their ſemi-diameter. To be *added*.

The ſemi-diameter of the ſun for every ſixth day, and of the moon for every noon and midnight at Greenwich, may be found in the Nautical Almanack; from whence the ſemi-diameters at the time of obſervation are to be computed by the rule in page 152 of the requiſite tables to the Nautical Almanack. This correction gives the apparent diſtance of the centers of the ſun and moon.

Second Correction. To clear the apparent diſtance of the effects of refraction, and parallax. To make this correction, two ſets of tables, with directions how to uſe them, are to be found among the requiſite tables to the Nautical Almanack. This correction may be more eaſily made from a ſet tables publiſhed by the Board of Longitude for that purpoſe.

Theſe two corrections being properly made to the apparent diſtance of the ſun and moon, the true diſtance of their centers, as ſeen from the center of the earth, will be obtained; and the time at the place of obſervation being known, the *longitude* of the place may be computed by the rules and tables belonging to the Nautical Almanack.

To take the Diſtance of the Moon from ſuch Stars as are ſelected in the Nautical Almanack for finding the Longitude at Sea.

THE diſtances of thoſe ſtars from the moon's center are alſo given in the Nautical Almanack for every three hours at Greenwich; from whence the diſtance from the enlightened limb of the moon may be computed as before.

Set the index to the diſtance thus computed. If the ſtar be to the left hand of the moon, the inſtrument muſt be adjuſted with the index at the firſt diviſion on the arch at A, as common, and held with its face upwards, if the ſtar is on the right hand, the contrary or new adjuſtment with the index at B is uſed. The moon will generally be bright enough to be ſeen, by reflection from the unſilvered parts of the glaſſes, and by two reflections will be ſufficiently darkened, ſo as not to hinder the ſtar from being ſeen when brought into contact with her. Direct the teleſcope to the ſtar, then put the inſtrument into the proper place as before, and giving it a ſweep round a line parallel to the line of ſight, the reflected image of the moon will paſs by the ſtar, and ſo near that you will ſee it in the field of the teleſcope. This will be a proof that the ſight is directed to the right ſtar. By turning the adjuſting ſcrew X, the enlightened limb of the moon (whether eaſt or weſt) may be brought into contact with the ſtar, and by giving the inſtrument a ſweep round a line parallel to the line of ſight, the enlightened limb of the moon may be made juſt to touch the ſtar as ſhe paſſes by it, and that in the middle between the two wires in the teleſcope.

The index will then ſhew the *apparent* diſtance of the ſtar from the enlightened limb of the moon, to which apply the two following corrections.

First Correction. The ſemi-diameter of the moon. This may be found in the Nautical Almanack for every noon and midnight at Greenwich, from whence her ſemi-diameter at the time of obſervation is to be computed by the rule in page 162 of the tables. If the obſerved or enlightened limb of the moon be the neareſt to the ſtar, the ſemi-diameter thus found is to be *added*; if the enlightened limb be the fartheſt from the ſtar, then the ſemi-diameter is to be *ſubtracted.* This correction gives the apparent diſtance of the moon's center from the ſtar.

Second Correction. To clear the apparent diſtance of the effects of refraction and parallax. This correction muſt be made from the tables, *&c.* as before directed for the ſun and moon.

Theſe corrections being properly made, the true diſtance of the moon's center from the ſtar, as ſeen from the center of the earth, will be obtained; and the time at the place of obſervation being known, the longitude of the place may be computed from the rules and tables belonging to the Nautical Almanack.

The ſtar to be uſed is always one of the brighteſt, and its poſition is always nearly in a line perpendicular to the line of the moon's horns, or which is the ſame thing, in the line of the moon's ſhorteſt axis produced. If you are not certain which is the right ſtar, having ſet the index to the diſtance of the ſtar from the moon, as found from the Nautical Almanack, hold the inſtrument as near as you can judge, ſo that its plane (ſeen edgeways) may coincide with the line of the moon's ſhorter axis, and moving it in that plane, ſeek the reflected image of the moon through the teleſcope; then give a ſweep with the inſtrument ſo as to turn it round the incident ray, that is, round a line paſſing from the moon to the inſtrument. By this ſweep the moon may keep in the field of the teleſcope, and the ſtar will be ſeen to paſs by her.

A readineſs in making theſe obſervations may certainly be acquired by practice; this has been fully proved by the great uſe that has of late years been made of this method to determine the longitude at ſea, and the many excellent improvements lately made in it, both in theory and practice, by the Aſtronomer Royal, leave no room to doubt but it will ſoon be brought into general uſe.

To obſerve the Altitude of the Sun at Land, by reflection from Water.

THE trough that contains the water ſhould be five or or ſix inches long and three or four inches wide; it muſt be laid on the ground, or on ſomething that is firm, and muſt be ſheltered from the action of the wind by a machine in the form of the ſlant roof of a houſe; this may be a wooden frame, with pieces of glaſs fixed into the ſides. The pieces of glaſs uſed for this purpoſe ſhould be truly flat, and the two ſurfaces of each glaſs ſhould be parallel to each other. This machine muſt be laid over the water-trough, but not to touch it, otherwiſe it may occaſion the water to ſhake.

Being thus prepared, move backwards till you ſee the reflected image of the ſun in the water; if this image be very bright, turn one or other of the darkening glaſſes before the teleſcope. Now, holding the inſtrument in a vertical plane, direct the ſight to the ſun's image in the water, then move the index till you ſee the other image, reflected from the mirrors come *down* to the ſun's image ſeen in the water, ſo as to touch but not to paſs it; then bring their edges into contact in the middle of the teleſcope.

The diviſions on the arch will ſhow the double altitude; to this you muſt add or ſubtract the index error, if any, according to which way it is; to half this ſum or difference add the ſun's ſemi-diameter, and ſubtract the correction for refraction; you will then have the true altitude of the ſun's center above the real horizon with the inſtrument adjuſted, and the obſervation taken in the new way, you take the altitude to 80 degrees.

The altitude of a ſtar is taken in the ſame manner as the altitude of the ſun, except that quickſilver muſt be uſed inſtead of water; for but few of the ſtars are bright enough to be ſeen reflected from water. The double altitude of the ſtar muſt be corrected for the index error, if any, then halved; the half being corrected for refraction only, gives the true altitude of the ſtar above the real horizon.

To obſerve correſponding Altitudes of the Sun.

FOR theſe obſervations it is neceſſary to be provided with a clock. The moſt proper times for making the obſervations are when the ſun is near the *prime vertical*, that is, the eaſt or weſt points of the compaſs. About this time in the forenoon obſerve ſeveral double altitudes of the ſun, write down the degrees and minutes ſhown on the arch, and alſo the exact time ſhown by the clock at each obſervation, and let the different obſervations made in the forenoon be wrote one below the other, in the order they are made.

In the afternoon ſet the index to the ſame degree and minute as the laſt morning obſervation. Note very exactly the time ſhown by the clock, when the ſun is obſerved to come down the ſame altitude, and write the time down on the right hand of the laſt morning obſervation. In the ſame manner proceed to find the time by the clock of all the altitudes correſponding to thoſe taken in the morning, and write down each one oppoſite to that morning one, to which it correſponds.

Take now the firſt pair of the correſponding altitudes, add them together, and to half their ſum add ſix hours; this being corrected for the change of the ſun's declination * between the morning and afternoon obſervations, you will have the time of ſolar noon derived from this pair of obſervations. Do the ſame for each pair, and taking the mean of the times thus found from each pair, you will have the exact time ſhewn by the clock at ſolar noon. From the equation of time in the ſecond page of every month in the Nautical Almanack you will find the difference between ſolar and mean time, which being added to or ſubtracted from the ſolar time, according as it is ſooner or later, gives the true time of ſolar noon, that is, the time that would be ſhewn by a clock that went perfectly right; compare this with the time actually ſhown by your clock, and its error will be given.

With a teleſcope that magnifies about 40 or 50 times, the eclipſes of Jupiter's Satellites may be ſeen at land, and the time at the place of obſervation being found as before, the longitude may be determined by the rules given every year in the Nautical Almanack for that purpoſe.

Thoſe directions reſpecting the longitude, &c. are moſt of them taken from Mr. Dolland's publication, and the Nautical Almanack.

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* This correction may be eaſily computed for any latitude from a table given for that purpoſe in the Nautical Almanack for 1769.

FINIS.

BRITISH MUSEUM

Plate I.

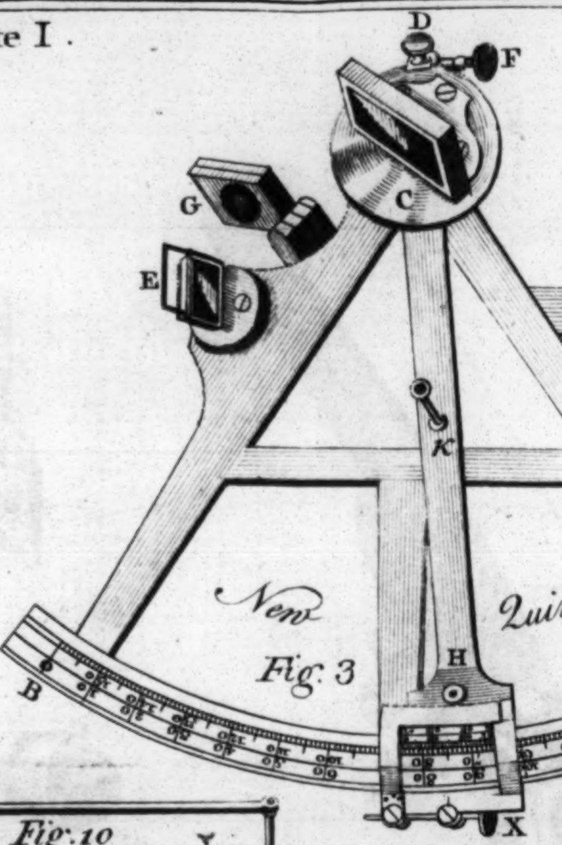


Fig. 3

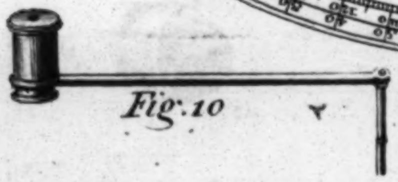
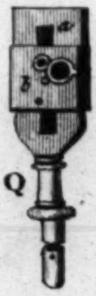


Fig. 10

Fig. 8.



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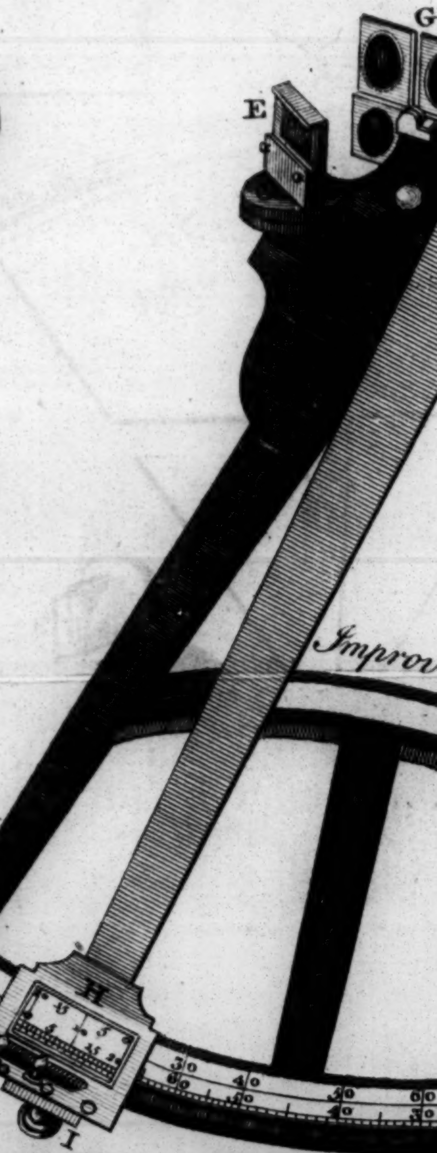

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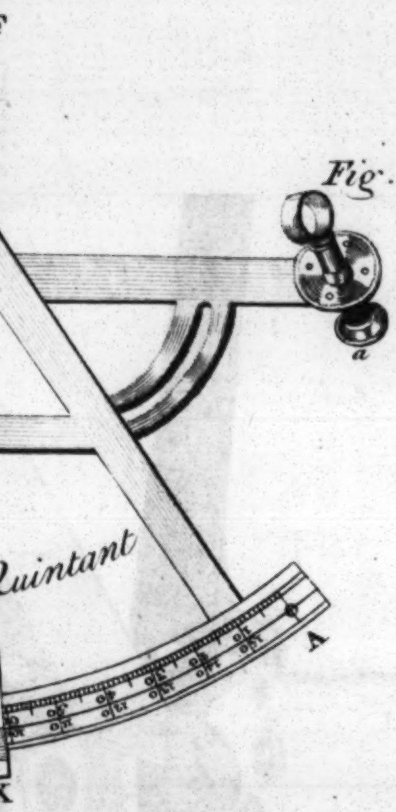


Fig. 6.

Fig. 5

Fig. 7.

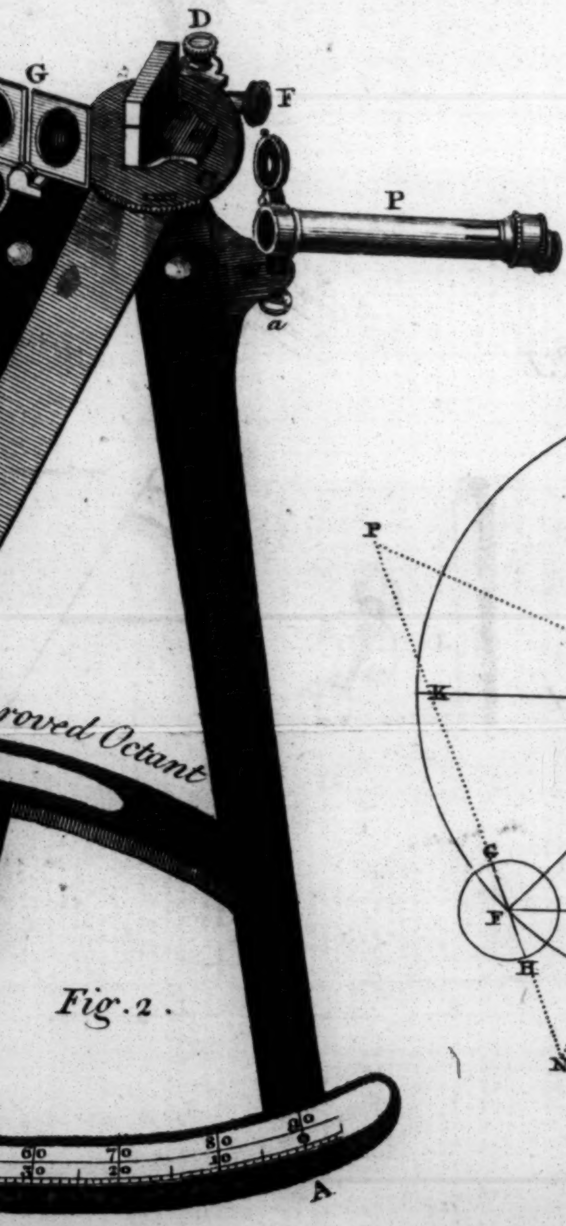
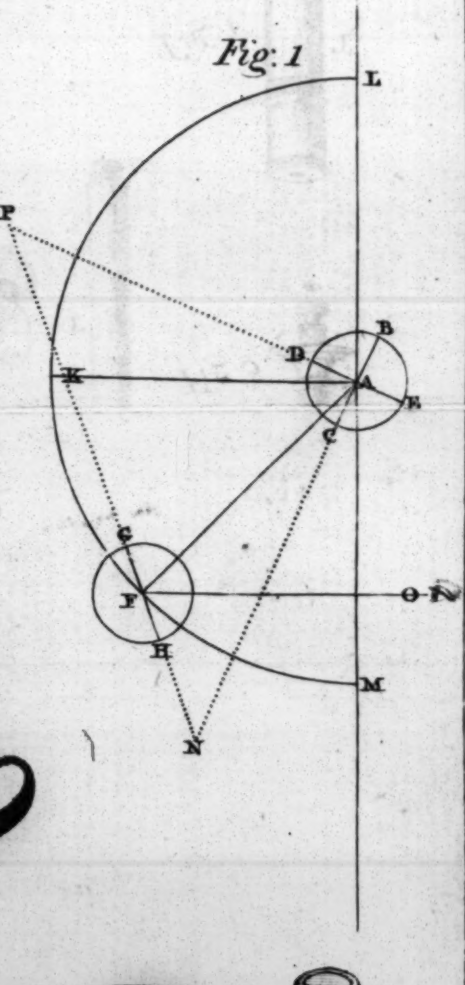
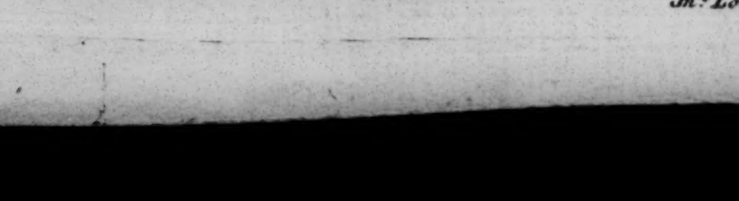


Fig. 2.

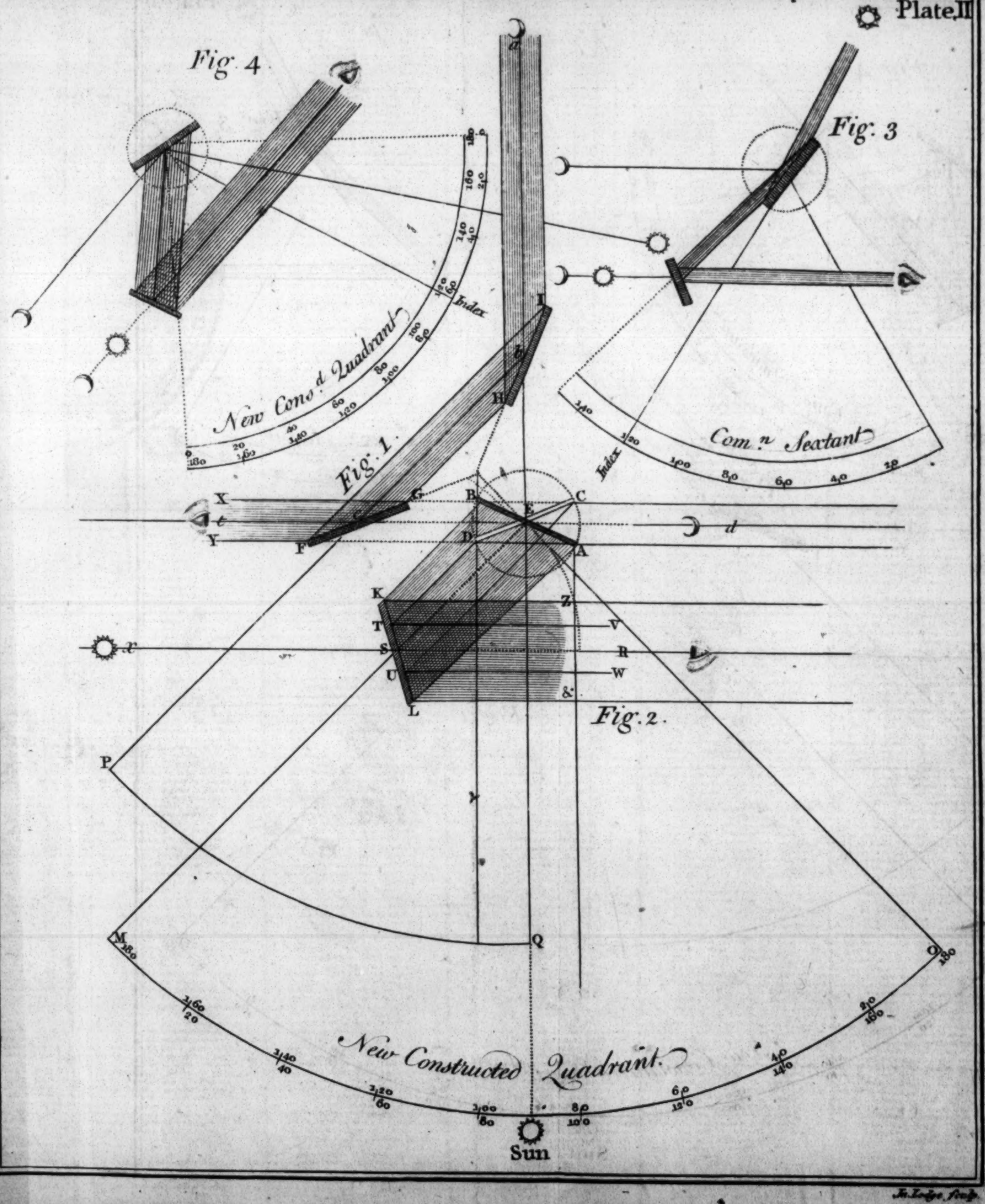
Fig. 1





Jnº Lodge sculp

Plate II



Jn. Lodge, sculp.

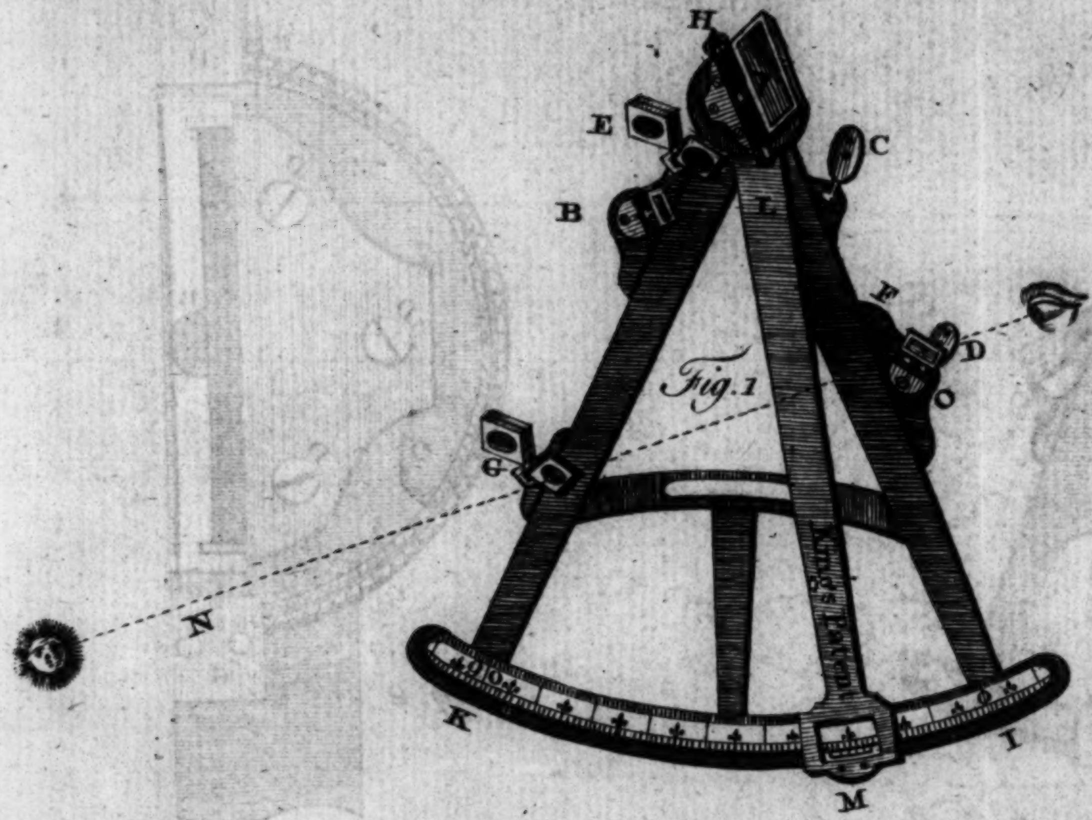


Fig. 1

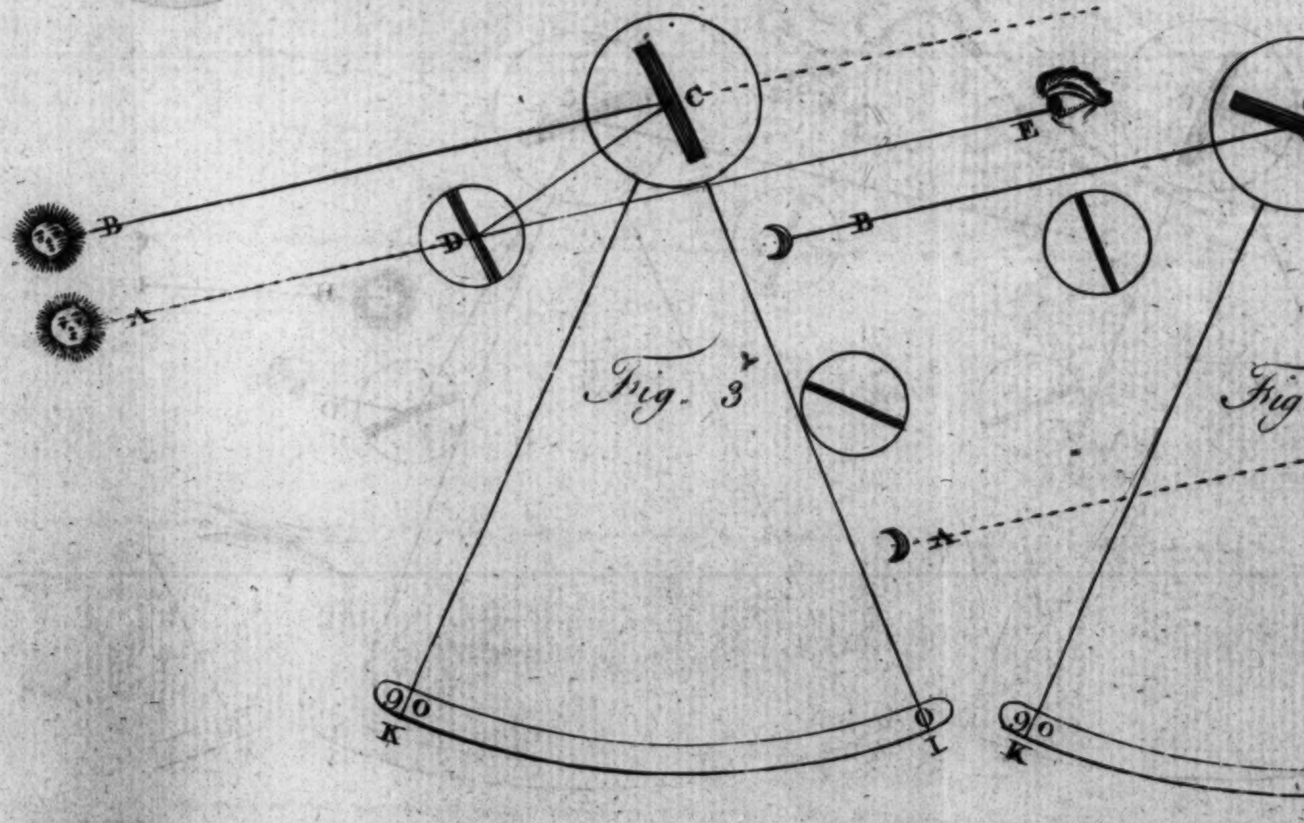


Fig. 3

Fig

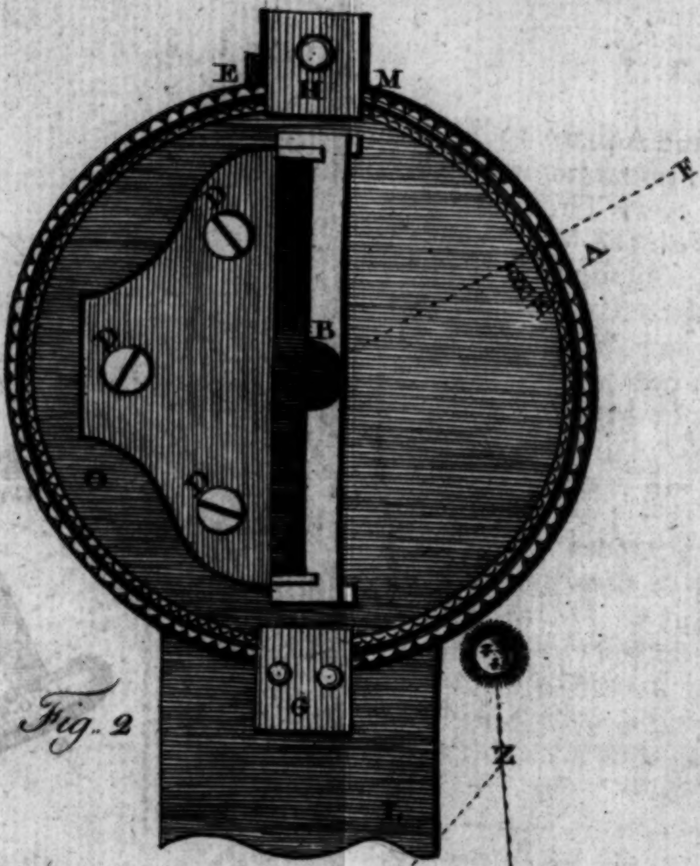


Fig. 2

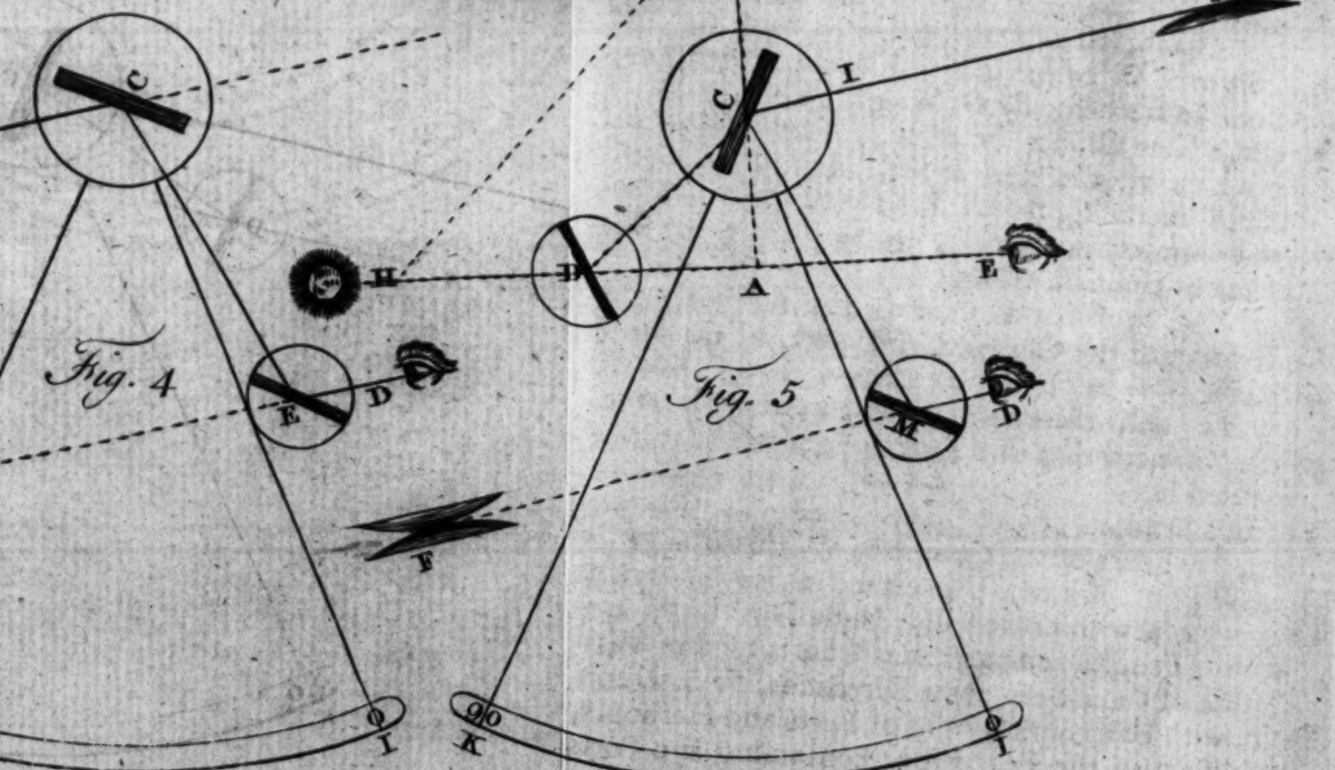


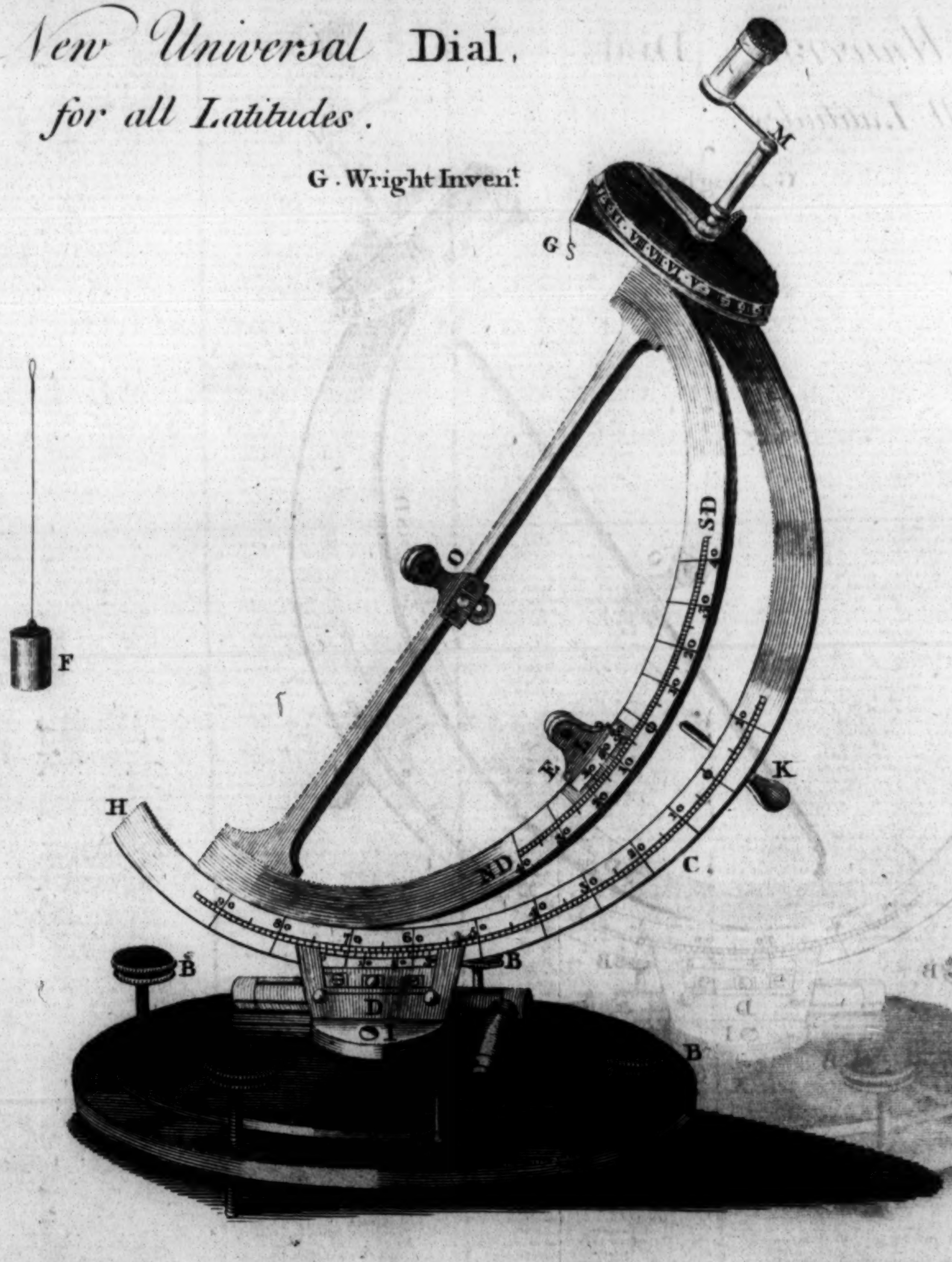
Fig. 4

Fig. 5

A New Universal Dial.

for all Latitudes.

G. Wright Invent.



Jn.o Lodge sculp.